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A Spatiotemporal Map of 40Hz Oscillations Across Visual Areas in an Awake Macaque

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INTRODUCTION

One of the proposed roles of gamma oscillations are to bind responses across brain regions during perception of sensory stimuli. In the present study we examined stimulus-related gamma oscillations in areas V1 and V4. We characterized the timing and laminar profile of the first oscillatory burst after a visual stimulus was presented.

IN SUMMARY

Our results show that the peak times of the first oscillatory bursts are significantly different in areas V1 and V4. The bursts in V1 occur at an earlier time (~94 ms) than those of V4 (~120 ms). We found no significant difference in peak times among the supragranular, granular and infragranular layers in the areas examined.

LOOKING AHEAD

•We plan to continue this study by looking at the timing of the stimulus related gamma oscillations in other areas within the visual system, including MT, V2, IP, VP, and STP.

•We will also compare the peak time of the first evoked component vs. the peak time of the first stimulus-related oscillatory burst across visual areas.

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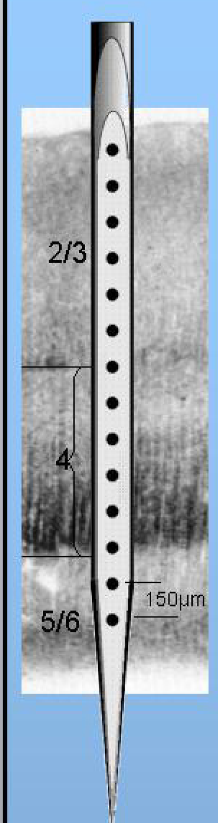
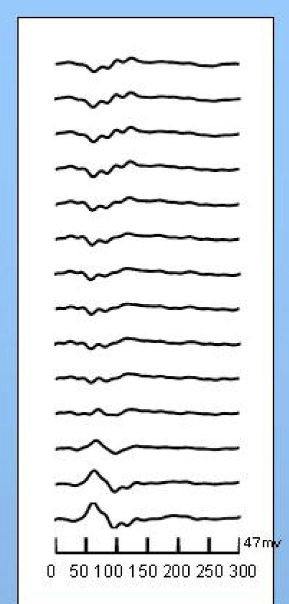
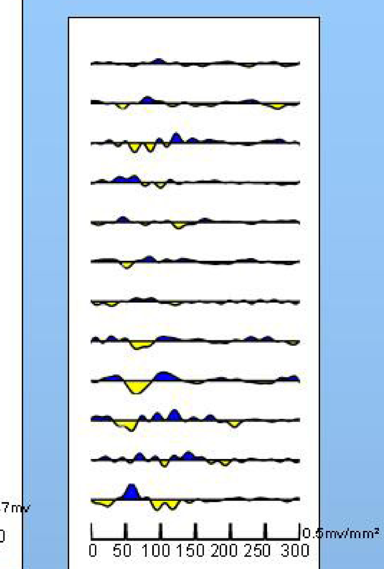
METHODS



Histological Section of Area V1, showing inserted 16-channel Electrode



Single-Trial Field Potential Profile



CSD Profile

RECORDING TECHNIQUES

Two male Macaque (Maccacca Fascicularis) monkeys were surgically prepared for chronic, awake recordings from areas V1 and V4. For each experimental session, a linear-array multielectrode was inserted into the brain and positioned perpendicularly to the laminae of the targeted region. Single-trial visual Event Related Potentials (ERP's) were recorded while the monkey performed a selective visual attention task. Current Source Density (CSD) profile was calculated to characterize transmembrane current flow.

BEHAVIORAL PARADIGM

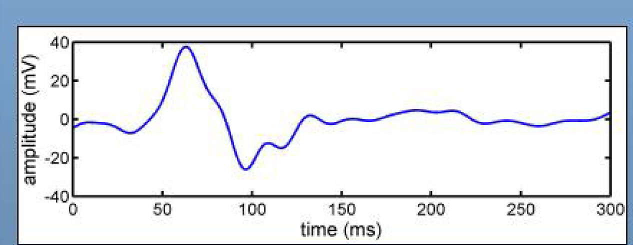
The monkey was presented with a series of target and non-target auditory and visual stimuli. In any given trial block, the monkey attended to either the auditory or visual modality and responded to the target of that modality while ignoring stimuli in the other modality. Correct responses were rewarded with a drop of juice. The visual stimuli consisted of two intensities. The non-target, red light flash was presented 86% of the time, while the target, dimmer intensity light flash, was presented 14% of the time. The auditory non-target and target stimuli were pure tones that varied slightly in frequency. The analyses presented here were performed on single-trial ERPs recorded in response to the non-target visual stimulus.

DATA ANALYSIS

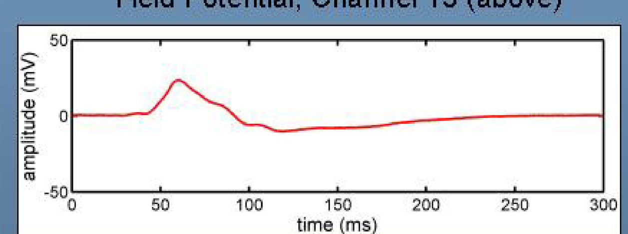
Single-trial ERPs capture both evoked (time- and phase-locked) and induced (non time- and phase-locked) activities. We were interested in the timing of induced gamma-band oscillations in V1 and V4. To analyze these induced oscillations, we modeled the evoked response and subtracted it from the single-trial ERP. The steps of this analysis are as follows:

1. Epoch Single-trial ERPs from 0 to 300ms, with zero denoting stimulus onset.
2. Model single-trial evoked activities using Differentially Variable Component Analysis (dVCA) (Knuth *et al.*, Submitted).
3. Subtract the modeled evoked activity from the actual single-trial ERPs to yield the residual signal containing induced activity.
4. Calculate the CSD profile of the residual signal.
5. Convolve a Morlet-based wavelet with the single-trial residual CSD signal to generate single-trial time frequency map.
6. Apply a peak detection algorithm to find bursts of oscillatory activity in the 34 to 50Hz range.
7. Model each burst as a two-dimensional Gaussian from which we find the peak time.

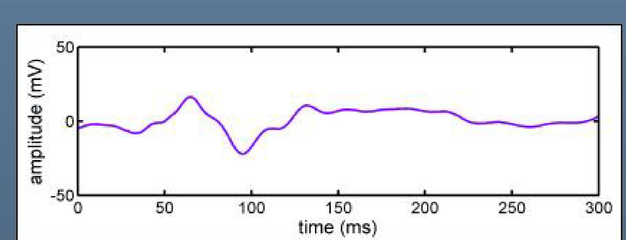
FP's



Field Potential, Channel 13 (above)

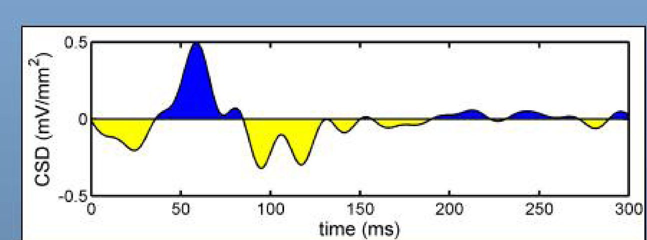


Modeled Evoked Potential of Field Potential

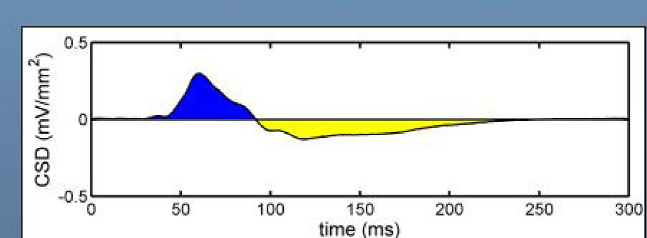


Residual Field Potential

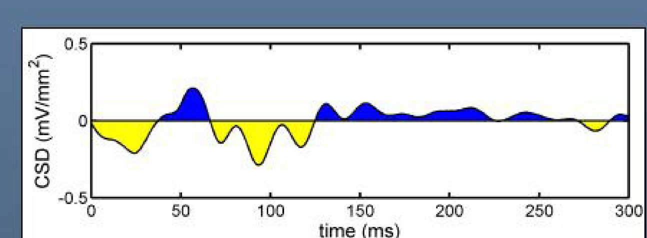
CSD



CSD Profile, Channel 13 (above)

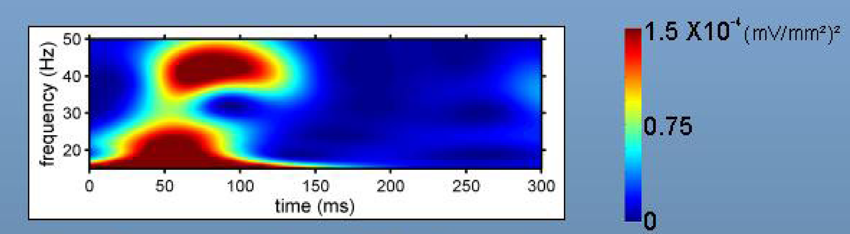


Modeled Evoked Potential of the CSD

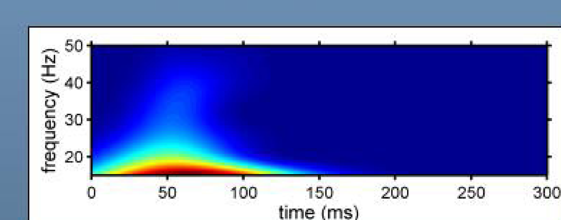


Residual CSD

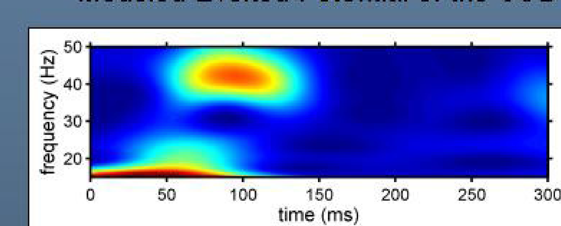
TF Maps



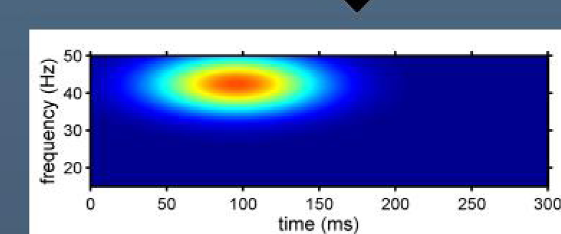
Time Frequency Map of CSD Channel 13



Time Frequency Map showing the Modeled Evoked Potential of the CSD



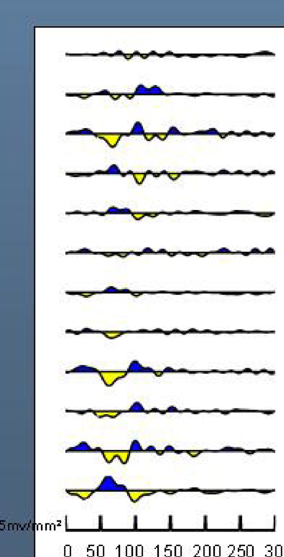
Time Frequency Map of Residual CSD



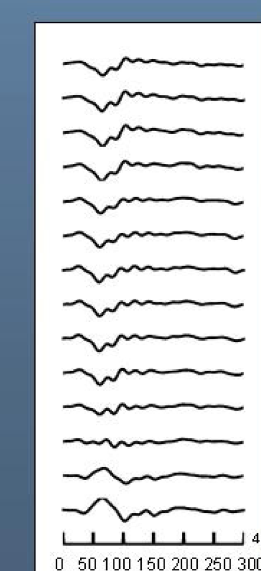
Gaussian Model

A gradient ascent algorithm is used to find the peak of the different oscillatory bursts. Eleven points in the time and frequency domain centered around the peak are utilized to fit a two-dimensional Gaussian to the oscillatory burst.

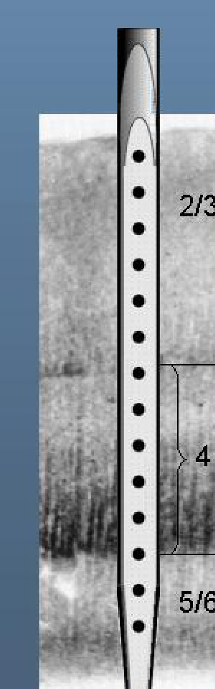
Induced Activity Non-Phase Locked



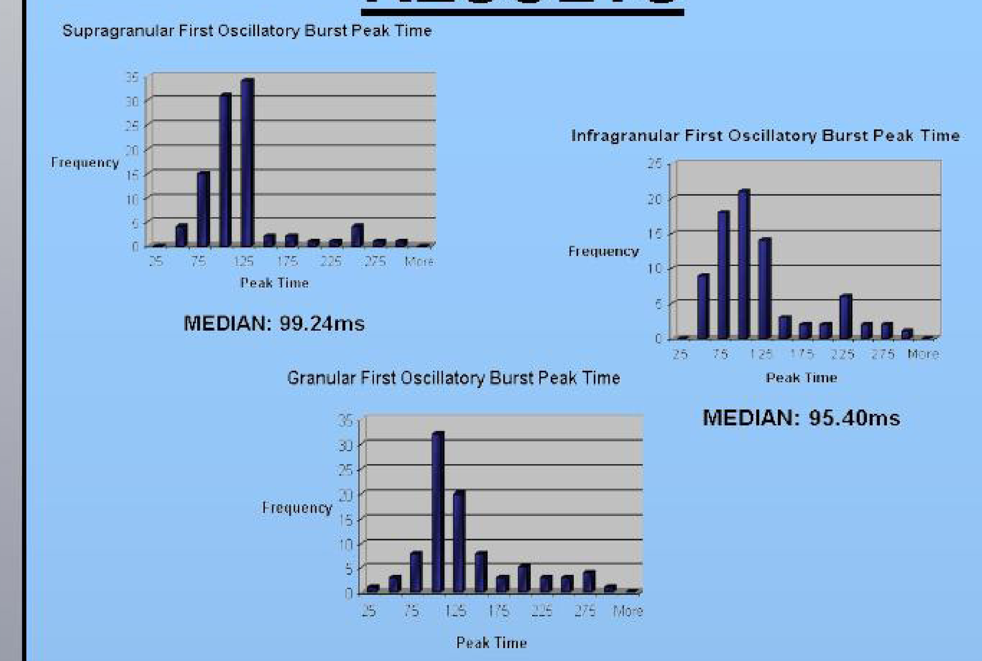
Profile of Residual CSD

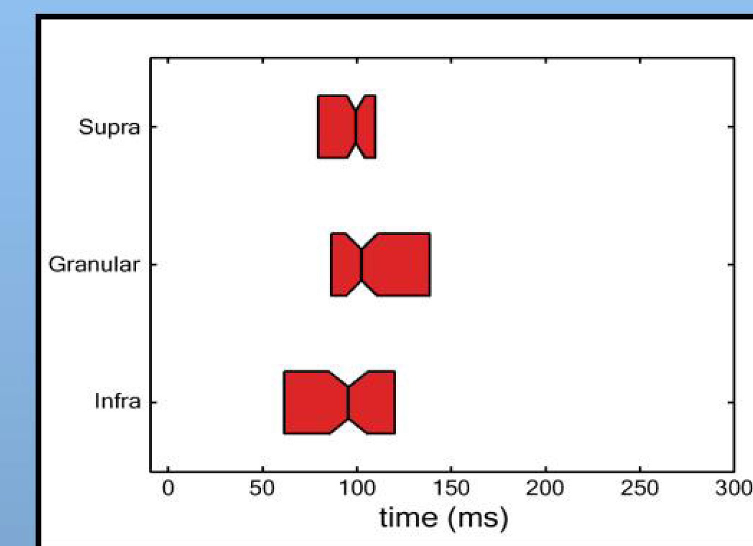


Profile of Residual FP

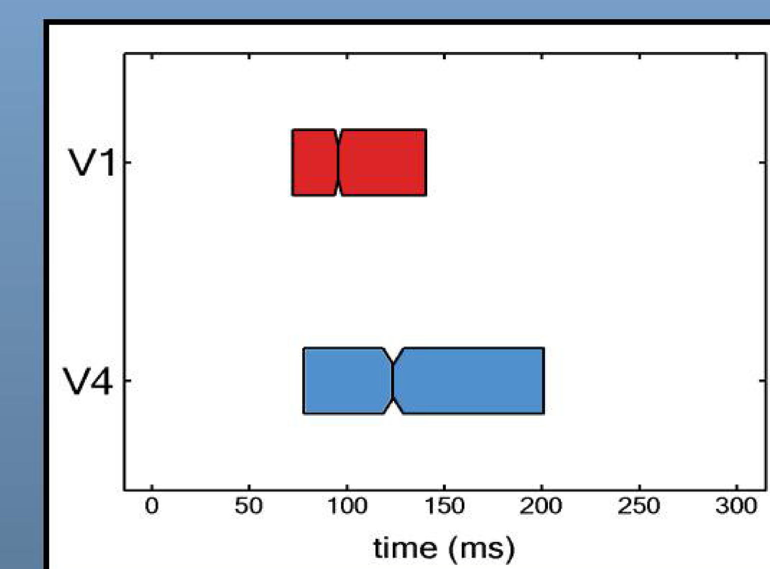


RESULTS

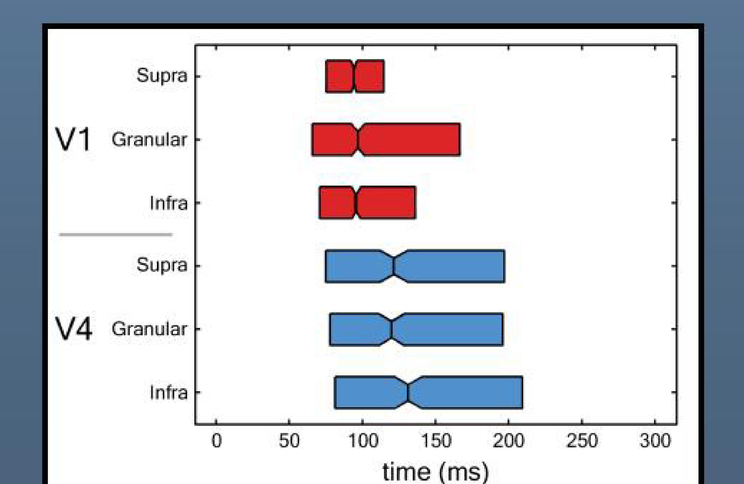




Gamma burst peak latency of each layer in V1 in a single experiment. There is no significant difference among peak latencies throughout layers.



Peak latencies of the oscillatory bursts in areas V1 and V4 across all experimental sessions. Peak latencies in area V4 are significantly longer than in area V1.



Distribution of peak latencies of the oscillatory bursts across V1 and V4 layers. There is no significant difference between layers within a given area, but all layers of V4 have a significantly longer latency than in area V1.